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The Efficiency of Sugarcane in its Use of Nitrogen Fertilizer Applications

George Samuels[1]

INTRODUCTION

Anyone associated with the growing of sugarcane knows that nitrogen fertilizers are needed for the maintenance of optimum production. Nitrogenous fertilizers are used in all sugarcane-growing areas of the world. The amounts and sources vary with area, soil, climate, and customs. The tendency in many of the leading cane-growing areas is to use higher levels of nitrogen than were used many years ago. Technical advances such as foliar diagnosis, aerial application, and usage of gaseous and liquid nitrogen sources, have all led to cheaper, wiser, and more effective utilization of the nitrogen applied to sugarcane.

Nevertheless, we lack many criteria by which to judge just how efficiently these nitrogen applications are being used by the growing cane. When we consider that nitrogen is being applied to cane in humid and irrigated areas at various rates, on plant crops and ratoons harvested at different ages with varying yields, we begin to wonder just how effective each pound is under these involved crop relationships. At present, the best criterion we have to judge nitrogen efficiency is to evaluate the yields produced by sugarcane when the element is applied. Unfortunately, the evaluation of the effectiveness of nitrogen applications on cane has been limited to random field observations by the growers. No study has been made to determine the efficiency of nitrogen under the varied crop relationships of Puerto Rico.

Many practical questions could be answered by a study of the efficiency with which nitrogen is used by growing sugarcane. Here are but a few that need answers:

Do plant canes or ratoons make more efficient use of the nitrogen applied? Does the efficiency of the applied nitrogen decrease as the application rate increases? Which uses applied nitrogen more effectively, cane grown in humid or in irrigated areas? Does sugar production suffer at high nitrogen-

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application rates? How many pounds of applied nitrogen does it take to produce a ton of cane or a ton of sugar?

PROCEDURES

Data from the sugarcane-fertilizer field experiments conducted by the Agronomy and Horticulture Department of the Agricultural Experiment Station of the University of Puerto Rico, for the period 1938–54, were utilized in order to answer some of these and other questions concerning nitrogen efficiency in fertilizing sugarcane. These experiments include 127 tests with 12 cane varieties and 9 soil types, and represent all major cane-producing areas of Puerto Rico. Data were selected from such of these tests as were associated with the specific nitrogen treatment that produced the highest sugar yields: that is to say, the quantity of nitrogen added per acre to produce the maximum proved response, statistically significant at least at the 5-percent level, in tons of available 96° sugar per acre. The data for the no-nitrogen application were used in those cases were no significant response was obtained from nitrogen. All experiments were replicated at least six times, the majority having nine replications per fertilizer treatment. Ammonium sulfate (20-percent nitrogen) was the nitrogen source used in all cases, and sufficient phosphate and potash were added to all nitrogen treatments so that these two elements were not limiting factors in the study of the nitrogen levels.

RESULTS

The results of the efficiency of sugarcane in its use of nitrogen have been arranged according to such specific factors as type of crop, water supply, pounds of nitrogen applied per acre, and tons of sugar produced per acre per month. The efficiency of sugarcane in utilizing the applied nitrogen is then discussed under these headings.

TYPE OF CROP

It is evident from the data presented in table 1 that fall and spring plantings were more efficient users of nitrogen than the ratoon crops. The plant cane required less nitrogen per acre, per month, and per ton of cane and of sugar to produce as much sugar per month (TSAM) as the ratoons.

The nitrogen needed per acre was lowest for the spring plantings at 109 pounds, and highest for the ratoons, at 140. On the basis of the nitrogen used per month of cane growth, fall plantings were the most efficient nitrogen users, requiring 7.2 pounds of nitrogen per month. The spring plantings were somewhat less efficient, needing 2.2 pounds more of nitrogen per acre, and the ratoon crops were the least efficient users of nitrogen, needing 4 pounds more nitrogen per month than fall plantings for optimum sugar

TABLE 1.—*Influence of the type of crop on the nitrogen efficiency of sugarcane*

Crop	Tests	Age at harvest	Amount of nitrogen per—				Yields per acre of—			
			Acre	Month	Ton of cane	Ton of sugar	Cane	Sugar	Cane per month (TCAM)	Sugar per month (TSAM)
	Number	*Months*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*	*Tons*
Fall planting (Gran Cultura)	25	17.3	125	7.2	2.0	16.7	61.4	7.5	3.6	0.43
Spring planting (Primavera)	13	11.6	109	9.4	2.4	20.1	46.4	5.4	4.0	.47
Ratoons	89	12.5	140	11.2	3.3	25.8	42.4	5.4	3.4	.43
Weighted means		13.4	138	9.8	3.0	23.2	46.1	5.8	3.4	0.43

yields. When we translate this into pounds of nitrogen applied per ton of cane produced, we still find the fall planting more efficient than the ratoon crops. The latter needed 1.3 pounds of nitrogen more per ton of cane produced than did the former. The same trend held in terms of nitrogen used per ton of sugar produced.

When we consider the yields per acre of cane and sugar the fall plantings with a longer growing season outproduced both the spring plantings and the ratoons. However, when we equalize these crops on a basis of growth per month, both for tons of cane and sugar, we find very little difference between any of them. Thus we find that, although on a basis of growth per month, our three types of cane crop were about equal in cane and sugar production, the fall plantings were the most efficient in their use of applied nitrogen, followed by spring plantings and ratoons in that order.

Why do plant canes require less applied nitrogen for efficient sugar production that do ratoons? The reason for their more efficient use of applied nitrogen may be that the plant canes have a better supply of reserve nitrogen in the soil to use than do ratoons. This larger supply of nitrogen for the plant canes comes from the large quantities of organic materials, such as old roots and cane trash, which were incorporated into the soil when the land was prepared for planting (2).[2] The ratoon lacks this large quantity of rapidly decaying organic materials. Therefore, this larger reserve of nitrogen made available to the plant canes means that less applied nitrogen is needed for the cane to produce optimum yields. Probably the sum total of nitrogen used per acre and per ton of cane is the same for plant crops and ratoons. The higher efficiency of nitrogen used by the plant canes is limited to ap-

[2] Numbers in parentheses refer to Literature Cited, p. 217.

TABLE 2.—*Influence of the water supply on the nitrogen efficiency of sugarcane*

Region in which plantings were located	Tests	Quantities of nitrogen needed per—				Yields per acre of—			
		Acre	Month	Ton of cane	Ton of sugar	Cane	Sugar	Cane per month (TCAM)	Sugar per month (TSAM)
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*	*Tons*
Humid	61	171	12.4	3.4	26.3	50.3	6.33	4.7	0.47
Semi-irrigated	39	127	9.0	3.4	26.5	37.3	4.79	2.9	.38
Irrigated	15	87	5.9	1.5	12.9	43.2	6.75	3.9	.47
Semiarid	12	53	3.5	1.3	10.2	40.7	5.39	3.0	.39
Weighted means		138	9.8	3.0	23.2	46.1	5.82	3.4	0.43

plied nitrogen only. The sugar-grower is obliged to increase his rate of nitrogen application for ratoons only because there is less reserve nitrogen in the soil for the ratoons to draw upon.

WATER SUPPLY

The cane grown in Puerto Rico is exposed to a variety of regional differences in water supply, ranging from humid to semiarid conditions. Canes growing under humid conditions where rainfall is adequate throughout the year for good growth (60–95 inches) used more nitrogen per acre than those grown under any other conditions (table 2). The other groups followed a descending order in nitrogen used per acre in reference to the water available as natural rainfall, ranging from semi-irrigated, to irrigated, to semiarid, the lowest nitrogen user per acre. The use of nitrogen per month, per ton of cane, and per ton of sugar also followed this order, with cane grown in humid areas using more nitrogen for optimum production, and that grown under semiarid conditions using the least.

When we consider yields per acre of cane, the humid area was highest with the irrigated second. However, irrigated cane stood first in tons of sugar per acre, with cane from the humid area close behind. Cane from semiarid areas produced better than that from semi-irrigated areas. On a per month basis, the humid area produced almost 1 ton of cane more than did the irrigated, but the irrigated cane's higher sucrose gave it equal ranking in reference to sugar produced per month. The humid-area cane thus used twice as much nitrogen in order to produce about the same amount of sugar per acre as the irrigated cane. In other words, irrigated cane is twice as efficient as humid-area cane in using the nitrogen applied. Also semiarid-grown cane (all experiments located at the Lajas Substation), under the conditions of these trials, proved to be over twice as efficient in nitrogen use as the semi-irrigated cane (all experiments located in the Isabela area).

TABLE 3.—*Influence of tons of sugar produced per acre per month (TSAM) on the nitrogen efficiency of sugarcane plant canes and ratoons*

Sugar per month (tons) (TSAM)	Mean sugar produced per month	Tests	Age at harvest	Amounts of nitrogen per—				Yields per acre of—		
				Acre	Month	Tons of cane	Tons of sugar	Cane	Sugar	Cane per month (TCAM)
Plant canes										
	Tons	*Number*	*Months*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*
Under 0.30	0.29	2	17.2	50	3.0	1.2	10.0	41.5	5.0	2.1
0.30–.39	.36	7	15.8	125	7.0	2.4	19.1	47.5	5.6	3.0
.40–.49	.44	16	14.4	117	8.1	2.0	18.5	54.1	6.3	3.8
.50–.59	.53	6	14.4	160	11.9	3.1	23.2	58.9	7.6	4.2
Over .60	.65	4	16.0	198	12.5	2.4	19.1	81.6	10.4	5.1
Ratoons										
Under 0.30	0.23	9	13.2	132	10.3	5.4	46.6	26.5	3.1	2.1
.30–.39	.35	18	12.4	99	8.1	3.1	24.0	32.9	4.3	2.5
.40–.49	.43	33	12.5	125	10.0	2.7	23.2	42.7	5.4	3.4
.50–.59	.53	25	12.7	154	12.3	3.1	23.0	51.0	6.7	4.0
Over .60	.61	4	12.2	175	14.4	3.3	23.7	55.4	7.5	4.6

TONS OF SUGAR PER ACRE PER MONTH

The best measure of sugar production from the field standpoint is the yield in tons of sugar per acre per month. This criterion takes into consideration cane-tonnage yields, sucrose-percent-cane, and age of crop. It allows for comparison regardless of the age of the crop. In order to see how nitrogen applications were utilized by the cane in producing tons of sugar per acre per month (TSAM), the values were classified into groups and the results are given in table 3.

Both for plant canes and ratoons there was a generalized increase in pounds of nitrogen per acre necessary for increasing the tons of sugar per acre per month, which means that more applied nitrogen was needed to produce more sugar. This is shown graphically in figure 1. We find that there were no appreciable differences in the quantities of nitrogen applied per ton of cane produced for any of the classes of TSAM, aside from the under-0.30 TSAM class. In other words, the same quantity of nitrogen was needed per ton of cane (2.5 pounds for plant canes, 3.1 for ratoons) for low sugar production per acre per month as for high. Therefore, it appears that cane utilizes applied nitrogen with the same efficiency at low or high rates of application per acre, the only difference being that more sugar per acre

per month is produced at the higher rates. Of course, it should be remembered that the rates of nitrogen used were up to 198 pounds per acre. Nitrogen additions above this rate would not be expected to show the same efficiency because of the law of diminishing returns.

A point often raised when speaking of nitrogen applications at various rates is the influence the nitrogen applied may have on sucrose production. If we plot the tons of cane per acre per month against the tons of sugar produced per acre per month, we obtain a highly significant linear relationship. The rise in cane tonnage was linear with increases in sugar, inasmuch as the sucrose-percent-cane tended to remain steady at all levels of tonnage production. Thus increased cane tonnage, due in part to higher levels of

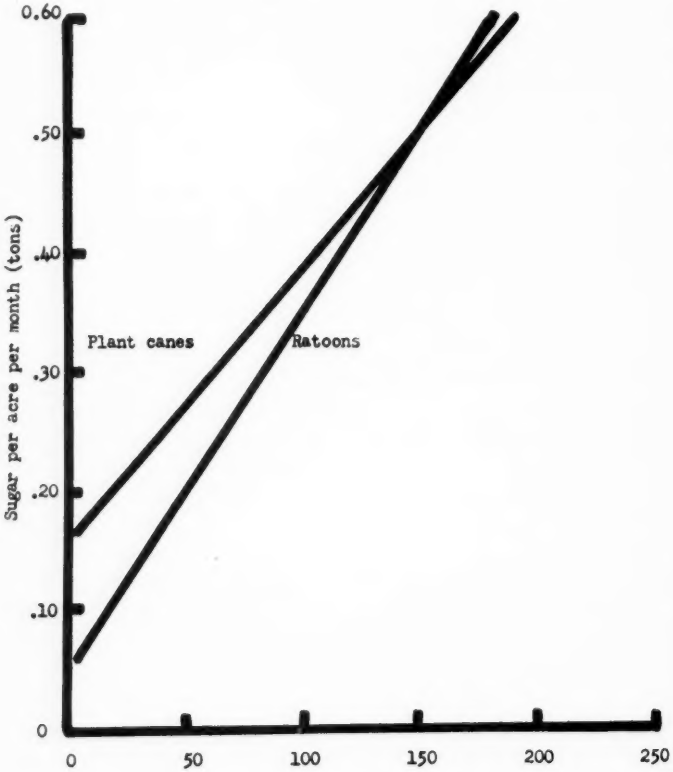

FIG. 1.—The influence of applied nitrogen on the production of sugar per acre per month by plant canes and ratoons.

TABLE 4.—*A comparison of the nitrogen efficiency of sugarcane producing over 0.50 ton of cane per acre per month in Hawaii and in Puerto Rico*

Location	Crop	Age at harvest	Amount of nitrogen used per			
			Acre	Month	Ton of cane	Ton of Sugar
		Months	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Hawaii	Plant cane	20.9	173	8.3	1.7	14.6
	Ratoon	18.8	175	9.6	2.1	17.4
Puerto Rico	Plant cane	16.0	175	12.1	2.8	21.6
	Ratoon	12.2	157	12.6	3.1	23.1

nitrogen application, did not show any tendency to lower sucrose values at the higher tonnage levels.

If we consider the production of 0.50 ton and over of available 96° sugar per acre per month as excellent production, we see that plant crops required a range of 160 to 198 pounds of nitrogen per acre, and ratoons 154 to 175 pounds. An average of 12 pounds of nitrogen per acre was used to produce over 0.50 ton of sugar per acre per month. In terms of tons of cane, this production of over 0.50 ton of sugar required about 3 pounds of nitrogen per ton of cane; in terms of sugar, the figure was about 23 pounds of nitrogen per ton of sugar.

Borden (1) determined the nitrogen efficiency of sugarcane growing in Hawaii. An interesting comparison of data from his cane producing over 0.50 ton of sugar per acre per month and the data from Puerto Rico is presented in table 4. We see that about the same amount of nitrogen per acre was needed in both islands, except that Puerto Rican ratoons, aged about 6 months less than Hawaiian, required about 20 pounds of nitrogen less.

Hawaiian cane used 5 pounds less of nitrogen per month. Hawaiian plant canes and ratoons used 1 pound of nitrogen less per ton of cane. There was more efficient nitrogen use with plant canes than with ratoons in both cane areas. Hawaiian cane needed 6 pounds less nitrogen than Puerto Rican cane per ton of sugar. Therefore, Hawaiian and Puerto Rican cane required about the same amounts of nitrogen per acre for optimum sugar yields, but Hawaiian cane used nitrogen a bit more efficiently and required about 3 pounds less per month or 1 pound less per ton of cane.

SUMMARY

The efficiency of sugarcane in using applied nitrogen was evaluated for 127 fertilizer tests. The evaluation was based on selected Station data which were associated with specific nitrogen treatments that produced the optimum sugar yield. The results obtained were as follows:

1. The fall and spring plantings were more efficient users of nitrogen than were ratoon canes.

2. Canes in humid areas were less efficient users of applied nitrogen than those in irrigated areas. Canes in semiarid areas used less nitrogen than did those in semi-irrigated areas.

3. There was an increase in tons of sugar per acre per month with increases in the nitrogen applied per acre.

4. The cane used about the same amount of applied nitrogen per ton of cane produced at either low or high rates of sugar production per acre per month.

5. Yields of tons of sugar per acre per month showed an excellent positive linear relationship with tons of cane per acre per month. The increase in cane tonnage did not show any tendency to lower sucrose values at the higher cane tonnages.

6. Taking the production of over 0.50 ton of sugar per acre per month as a criterion of very good sugar yields, this required an average of 3 pounds of nitrogen per ton of cane and 23 pounds per ton of sugar.

7. When cane nitrogen efficiency in Puerto Rico and Hawaii in producing over 0.50 ton of sugar per acre per month was compared it was found that both required about the same rates of nitrogen per acre, but in Hawaii the cane used 3 pounds less nitrogen per month, 1 pound less nitrogen per ton of cane, and 6 pounds less nitrogen per ton of sugar than Puerto Rico.

RESUMEN

La eficiencia del uso del nitrógeno para abonar la caña de azúcar se evaluó tomando en consideración los resultados de 127 experimentos de abonamiento. Esta evaluación se basó en aquellos datos en los cuales el tratamiento específico con nitrógeno estaba asociado con el rendimiento óptimo de la caña.

Los resultados que se obtuvieron fueron los siguientes:

1. Las siembras de otoño y de primavera usaron el nitrógeno más eficientemente que los retoños.

2. Las cañas de las áreas húmedas no usaron el nitrógeno tan eficientemente como las de las áreas bajo riego. Las cañas de las áreas semiáridas usaron menos nitrógeno que las de las áreas en donde se usaba el riego a media capacidad.

3. En cuanto a las toneladas de azúcar producidas por mes, hubo un aumento general en el uso de libras de nitrógeno por acre, para asímismo aumentar el número de toneladas de azúcar por mes.

4. Irrespectivamente de que la producción de azúcar por acre por mes fué baja o alta, la caña usó casi la misma cantidad de nitrógeno aplicado por tonelada de caña producida.

5. Los rendimientos de azúcar por acre por mes, demostraron una relación positiva linear excelente con el número de toneladas de caña pro-

ducido por acre por mes. El aumento en el tonelaje no demostró tendencia alguna a bajar los valores de sacarosa en la caña, aún en las producciónes más altas.

6. Cuando se tomó como criterio una producción sobre 0.50 toneladas de azúcar por acre por mes, se requirieron 3 libras de nitrógeno por tonelada de caña producida y 23 libras por tonelada de azúcar.

7. Cuando se comparó la eficiencia para producir sobre 0.50 toneladas de azúcar por acre por mes, entre Puerto Rico y Hawaii, en ambos países la caña necesitó casi igual proporción de nitrógeno por acre, pero en Hawaii se usaron 3 libras menos de nitrógeno por mes, una libra menos por tonelada de caña y 6 libras menos por tonelada de azúcar que en Puerto Rico.

LITERATURE CITED

1. Borden, R. J., Crop relationships with special reference to nitrogen efficiency, *Hawaiian Planters' Rec.* **48** 65–72, 1944.
2. Samuels, G., Landrau, P., Jr., and Capó, B. G., The response of sugarcane in Puerto Rico to various nitrogen sources, *J. Agr. Univ. P. R.* **36** (3) 231–9, 1952.

Influence of Phosphate Fertilizers on Pineapple Yields

G. Samuels, P. Landrau, Jr., and S. Alers Alers[1]

INTRODUCTION

Nitrogen and potassium have long been recognized as required fertilizer elements for high yields and good quality in the commercial growing of pineapples. Without nitrogen fertilizers, yields are poor and plant growth suffers in general. The omission of potash fertilizers may not always reduce pineapple yields, but the flavor and color of the pineapple generally suffers. However, the case for phosphate fertilizers is not as clear-cut. Although used by pineapple growers, phosphate fertilizers generally have had no decisive influence on the crop in controlled fertilizer experiments.

As early as 1925, Henricksen (2)[2] found that phosphate fertilizers used by the growers at commercial rates were giving lower pineapple yields per acre than when no phosphate were applied. Since then other workers, such as Pennock (4), González Ríos (1), and Schapelle (6), have all obtained lower yields of pineapples when phosphate fertilizers were applied.

All of this pineapple work has been carried out with the Red Spanish variety grown commercially in Puerto Rico. Nightingale (3), in Hawaii, found that, for the Smooth Cayenne variety, yields either were not increased or were reduced if phosphate fertilizers were added to the soil around pineapples which had a sufficient phosphate supply. Yield increases were obtained only where plants low in phosphorus were fertilized with phosphate just prior to and during blossom-bud differentiation.

PROCEDURES

To study the influence of phosphate fertilizers on pineapple yields, data were utilized from a series of pineapple-fertilizer experiments with the Red Spanish variety established throughout the pineapple-growing area of Puerto Rico. Detailed procedures as to design and treatments were given in a previous article (5). In these experiments, 28 pounds of P_2O_5 per acre per application was applied in from one to four applications at 4-month intervals, starting at time of planting. This was done in such a manner that rates of 0, 28, 56, 84, and 112 pounds P_2O_5 per acre per crop were applied. Nitrogen and potash were added to all treatments at optimum rates.

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[2] Numbers in parentheses refer to Literature Cited, p. 223.

Two experiments, one with a plant crop and a ratoon and another with a plant crop only, were grown at the Corozal Substation on a Lares clay. This is a medium-friable acid clay occurring in terrace formations from materials washed from the lower Tertiary clays and shales. The soil pH

TABLE 1.—*Mean yields of Red Spanish pineapples grown at various phosphate levels used in 1 to 4 applications*

Treatment[1]	Mean yield of pineapples per acre for the number and rate of phosphate (P_2O_5) applications per acre indicated—				Mean
	1 application, 28 pounds P_2O_5	2 applications, 56 pounds P_2O_5	3 applications, 84 pounds P_2O_5	4 applications, 112 pounds P_2O_5	
Corozal, experiment 1, plant crop (1953–54)					
No phosphate	10.7	12.2	15.2	14.2	13.1
Phosphate	12.5	13.7	15.0	13.5	13.7
L.S.D. at 5 percent	2.0	2.0	2.0	2.0	0.7
Corozal, experiment 1, ratoon crop (1954–55)					
No phosphate	12.5	8.8	12.7	11.7	11.4
Phosphate	8.6	11.3	9.8	9.0	9.7
L.S.D. at 5 percent	2.9	2.9	2.9	2.9	1.5
Corozal, experiment 2 plant crop (1954–55)					
No phosphate	8.3	7.8	11.0	12.6	10.0
Phosphate	8.4	9.8	10.4	11.6	10.1
L.S.D. at 5 percent	2.1	2.1	2.1	2.1	1.0
Manati, plant crop (1954–55)					
No phosphate	10.1	16.2	15.6	16.3	14.6
Phosphate	13.2	12.0	15.3	14.6	13.8
L.S.D. at 5 percent	6.0	6.0	6.0	6.0	2.4
Mean of all experiments					
No phosphate	10.4	11.3	13.6	13.7	12.3
Phosphate	10.7	11.7	12.6	12.2	11.8
L.S.D. at 5 percent	3.3	3.3	3.3	3.3	1.5

[1] All treatments received nitrogen and potash fertilizers.

was 4.8. Another experiment was made on a plant crop grown on a Bayamón sandy clay loam at the Florida farm of the Land Authority of Puerto Rico at Manatí.

RESULTS

The results of the phosphate treatments are given in table 1. In only one case (Corozal experiment 1, plant crop, first application of 28 pounds P_2O_5), did yields increase almost significantly when phosphates were used. In general, there were no significant yield increases from the use of phosphate fertilizers on pineapples. The means of all the experiments showed a steady decrease in yield with increasing amounts of phosphate applied after the second application. For the treatments with 28 and 56 pounds of P_2O_5 per acre, applied up to 4 months after planting, some increases in yields were obtained in all cases except two. For the treatments with 84 and 112 pounds of P_2O_5 per acre, applied 8 and 12 months after planting, decreases in yields were obtained in all cases.

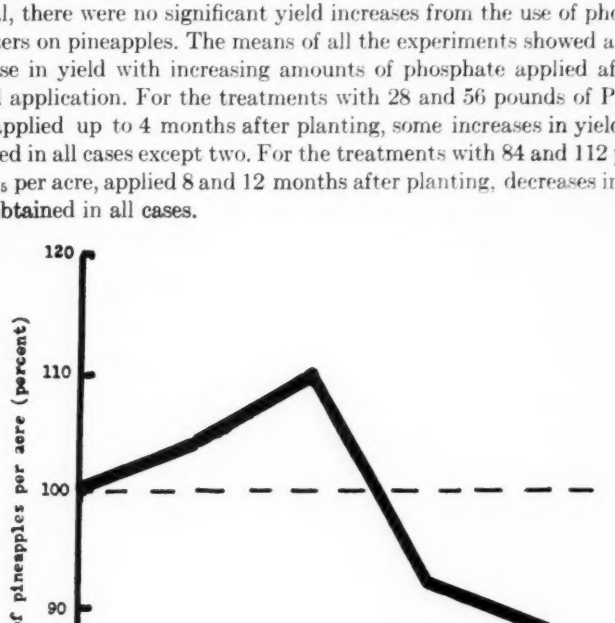

FIG. 1.—The influence of phosphate applications on relative yields of pineapples.

These factors were plotted graphically to evaluate the relationship between phosphate additions to the soil and pineapple yields. In order to compare all experiments on the same basis, the yields in tons of pineapples per acre were changed to relative yields. The relative yield was calculated using the yield with no phosphate applied as 100. The influence of rates of phosphate application on these relative yields is shown graphically in figure 1. We see that 28 pounds of P_2O_5 increased yields only 4 percent, to 104; and with 56 pounds of P_2O_5 they rose to 110. However, with 84 pounds of P_2O_5, yields dropped to 92, or 8 percent lower than when no P_2O_5 was used. Finally where 112 pounds of P_2O_5 were used yields declined to 88, or 12 percent less than where no phosphate were used.

From these experimental data, the maximum quantity of P_2O_5 per acre which would not depress pineapple yields was 56 pounds. This safe limit, of course, applies only to the experimental data, but inasmuch as previous research has shown depressed yields with phosphate applications averaging over 100 pounds of P_2O_5 per acre, the pineapple grower should be very cautious in applying phosphate fertilizers to his plants. Although small quantities are not harmful and may prove beneficial, applications now used by the farmer with mixed commercial fertilizers are many times over the safe limit and may depress pineapple yields.

DISCUSSION

To the inquisitive mind, the question arises as to why phosphate applications depress pineapple yields, even when used at relatively low rates as compared to applications made to other crops. Nightingale, working with pineapples in Hawaii, felt that when supplies of phosphate to the pineapple plant were adequate, further additions of phosphate fertilizers served only to create an unbalanced nutrient level in which the phosphate depressed the influence of nitrates (3). If this condition were coupled with high carbohydrate reserves in the plant, the phosphate additions depressed the much-needed nitrates to the extent that yields actually suffered. He also stated that, under conditions of low carbohydrate reserves, when nitrate needs are lower, the depressing effect of the phosphate may actually be beneficial and help increase yields. For these reasons, phosphate additions under Hawaiian conditions have produced a mixed response on yields. When Nightingale critically evaluated the carbohydrate, nitrate, and phosphorus levels at the crucial period just prior to and during blossom-bud differentiation, he could determine when phosphate fertilizers were needed. If carbohydrate and nitrate reserves were not high and phosphorus levels were low, additions of phosphate fertilizers proved of no value for increasing pineapple yields.

Another point to be considered in relation to phosphorus is its influence

on the time of fruiting. It has been shown that heavy applications of phosphate hasten the maturity of other crops (3). This ripening effect has been observed many times by the authors where high phosphate has been used on pineapples. Pennock (4) found that 60 pounds of P_2O_5 per acre depressed yields 5 percent with Red Spanish pineapples growing on a Bayamón silty clay loam at Arecibo. This lowered yield was due mainly to a change in size of fruit. Where phosphates were used there was a significant increase in the number of culls or small fruits unfit for market. It appears that the addition of phosphate hastened maturity and produced smaller fruits.

At present our pineapple growers use too much phosphate fertilizers. Although they have decreased somewhat the quantity used, rates are still too high in many cases—for example 172 tons of P_2O_5, equivalent to 860 tons of superphosphate (20 percent P_2O_5), were sold as pineapple fertilizer in the period 1950–51. At a price of $37.50 per ton for superphosphate, this represents $32,250 spent for phosphates in one year. Of course, some minimum amount of phosphate could be useful in mixed fertilizers for pineapples, but a quantity equivalent to 50 pounds of P_2O_5 per acre appears to be adequate. If this amount had been used in 1950-51, instead of the old rates, there would have been a saving of $23,062 to the pineapple growers.

SUMMARY

The use of phosphate fertilizers for pineapples has produced the following results in various experiments carried on by this Station:

1. From none to small yield increases were obtained with phosphate used at rates up to 56 pounds of P_2O_5 per acre and applied up to 4 months after planting.

2. Yields were depressed when 84 and 112 pounds of P_2O_5 per acre were applied.

3. The maximum quantity of phosphates that could be used for increasing yields under the experimental conditions was 56 pounds of P_2O_5 per acre.

4. The depressing influence of phosphates on yields is believed to be due to its action in lowering nitrate intake when carbohydrate and phosphate reserves are ample.

5. High-level phosphate additions serve to hasten pineapple fruiting and produce more culls.

6. At present growers use too much phosphate in their pineapple fertilizer applications, and a distinct saving in money could be realized if rates of phosphate application were lowered.

RESUMEN

El uso del fosfato para abonar la piña ha demostrado lo siguiente:

1. Las aplicaciones de P_2O_5, a razón de 56 libras por acre, a los 4 meses

de sembrada la piña, produjeron rendimientos insignificantes o relativamente bajos.

2. Los rendimientos decayeron más cuando las aplicaciones de P_2O_5 se aumentaron en 84 y 112 libras por acre.

3. Bajo las condiciones de los experimentos, se determinó que 56 libras de P_2O_5 fué la aplicación máxima para aumentar el rendimiento de la piña.

4. Se cree que la influencia depresiva de los fosfatos sobre los rendimientos se debe a su tendencia de aminorar la entrada del nitrógeno, cuando las reservas de hidratos de carbono y fosfato son amplias.

5. Las adiciones considerables de fosfato precipitan el tiempo de la florecida en la piña, e inducen la producción de un mayor número de frutas de mala calidad.

6. Actualmente los productores de piña usan más fosfato que lo adecuado, por lo que tienen margen para hacer algunas economías, si disminuyeran las cantidades de fosfato que le aplican a sus piñales.

LITERATURE CITED

1. González Ríos, P., A pineapple fertilizer experiment, *J. Dept. Agr. and Labor P. R.* 3 6–13, 1919.
2. Henricksen, H. C., Fertilizers: Some pineapple problems, Article 16, Agr. Notes, Federal Exp. Sta., Mayagüez, P. R., 1942.
3. Nightingale, G. T., Potassium and phosphate nutrition of pineapple in relation to nitrate and carbohydrate reserves, *Bot. Gaz.* 104 191–223, 1942.
4. Pennock, W., Nutrient requirements of pineapples on Bayamón silty clay, Report of the Federal Exp. Sta., Mayagüez, P. R., 62–8, 1939.
5. Samuels, G., Landrau, P., Jr., and Olivencia, R., Response of pineapples to the application of fertilizers, *J. Agr. Univ. P. R.* 39 (1) 1–11, 1955.
6. Schapelle, N. A., Fertilizer studies with pineapples in Puerto Rico, *J. Agr. Univ. P. R.* 26 41–60, 1942.

Results of Lime and Minor-Element Fertilizer Research in Puerto Rico, 1949-50

Pablo Landrau, Jr., and George Samuels[1]

INTRODUCTION

About a hundred years ago Julius Sachs demonstrated that such elements as sulfur, calcium, magnesium, and iron were essential to plant growth. Less than 25 years ago, such minor elements as copper and zinc were being used by the farmer to correct deficiencies in citrus and vegetable crops grown on peat or muck soils. Today, the use of minor-element fertilizers for certain crops with high requirements for a specific minor element, or in soils lacking a good available supply of the element, is a common practice in many parts of the world.

Since minor-element fertilization has benefitted so many crops and soils in the United States, it was only natural that agriculturists in Puerto Rico began to ask whether they would prove beneficial to Puerto Rican agriculture. The pineapple growers were first to recognize the specific benefit of minor-element fertilizers. Work by Schappelle (17),[2] Hopkins (8), and Ramírez Silva (14) showed that an iron chlorosis was present in most pineapples growing in Puerto Rico. The growers found that the use of iron sprays were necessary to obtain satisfactory pineapple yields, and growth, especially in soils with a pH above 5.5 (13).

As early as 1927, attempts were made to increase the sucrose content of sugarcane by applying manganese salts to the soil, but the results were negligible. Again in 1941-42, an experiment was conducted to try to correct a cane chlorosis at Central Guánica on a Fraternidad clay, a calcareous soil type, with treatments including sulfur, copper, iron, manganese, and molasses. The use of 1,000 pounds of sulfur produced the highest yields. In 1949, full-scale field experiments were initiated in minor-element fertilizer research beginning with an experiment on sugarcane at Guánica.

OBJECTIVE

It is the purpose of this paper to give the results of minor-element fertilizer experiments conducted by the Agronomy and Horticulture Department of the Agricultural Experiment Station of the University of Puerto Rico during 1949-54, and to summarize the results in terms of practical application to specific crops or soils in Puerto Rico.

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[2] Numbers in parentheses refer to Literature Cited, p. 234.

PROCEDURES

All experiments conducted in this work were laid out in the field according to well-known experimental designs with sufficient replications to insure reliable statistical analysis. The majority of the experiments were replicated nine times. The experimental designs were mainly triple lattices, and in a few experiments, randomized blocks. Most of the experiments were so designed that both major- and minor-element fertilizers were studied in the same experiment. In all experiments the minor-element treatments as well as the check treatment received adequate supplies of the major-fertilizer elements (N-P-K). In testing the need for a particular minor element, the treatment consisted in adding the minor element to the soil along with a major-element fertilizer and comparing the yield obtained with that of the treatments where only the major-element fertilizer was added.

RESULTS

The results of the experiments will be grouped under the specific crops rather than by the minor elements applied. It is felt that this will give a more comprehensive picture of the minor-element fertilizer needs of the various crops of Puerto Rico.

SUGARCANE

The majority of the work with minor-element fertilizers has been centered around sugarcane, since this crop is the main agricultural enterprise in Puerto Rico and is grown almost everywhere in the Island.

The results of eight experiments carried out with sugarcane are summarized in table 1. In general, no minor-element fertilizer gave appreciable yield increases in all experiments. However, certain significant yield increases were realized for particular soils. Considering each fertilizer element used, the following results were obtained:

Calcium

For the acid soils (pH below 5.5) such as the Lares clay, Vía silty clay, and some areas of the Coto clay, the use of calcium as lime ($CaCO_3$) produced significant increases in yield of available 96° sugar per acre. This increase was due mainly to an increase in tons of cane per acre, rather than sucrose-percent-cane. Lime was of no value in soils with a pH above 6 (Tiburones muck and Toa silty clay loam).

Experiments reported in the literature have shown a variable response to the lime added. Doty, in Hawaii (7), found poor juice purities and poor quality ratios when lime was applied; however, water-culture experiments (2) have shown that calcium-deficient canes had greatly increased

TABLE 1.—*Relative yields obtained on various soils when lime and minor-element fertilizers were used for growing sugarcane*[1]

Calcium or minor element used	Source	Range of rates used per acre	Range of relative responses in yield of available 96° sugar per acre to minor element applications on—							Average
			Coto clay	Lares clay	San Antón silty clay loam	Santa Isabel siltyl clay	Tiburones muck	Toa silty clay loam	Via silty clay	
		Pounds								
Boron	Borax	35–100	92–108	105–110	108	79[2]–101	92–103	97–104	95	101
Calcium	Calcium carbonate	4,000–20,000	94–111[2]	110–114	—	—	94–103	92–102	100–125[3]	105
	Calcium sulfate (gypsum)	1,000–4,000	—	—	—	94–99	—	98–110	—	100
Copper	Copper sulfate	25–300	87–100	—	112[2]	88[2]–98	91–96	97–107	98–108	102
Iron	Ferrous sulfate[4]	35–100	—	—	109	93–106	—	104–111[2]	—	105
	Chelated iron (EDTAfe)	50	—	—	—	96	—	—	—	96
Magnesium	Magnesium oxide	50–1000	101–108	102–112	101	93–101	—	88–106	96–108	102
	Magnesium sulfate (Epson salt)	300–500	95–97	—	—	94–100	92–100	—	—	96
Manganese	Manganese sulfate	35–100	96–108[2]	94–100	97	95–98	97–98	103–105	100–106	101
Sodium	Sodium chloride	100–500	—	—	—	—	—	92–101	—	99
	Sodium sulfate	300	—	—	—	—	—	83[2]–107	—	96
Sulfur	Sulfur	1,000–4,000	—	—	109	90–101	—	—	—	103
Zinc	Zinc sulfate	25–100	101–110[2]	93–111	105	92–101	99–108	93–98	93–110	103
Mixtures	Fritted trace elements (FTE)[5]	200	—	—	—	100	96	—	—	98

[1] All treatments received complete mixed fertilizers (N—P_2O_5—K_2O); the check in each experiment received no minor-element application. Its yields are used for the base of 100.

[2] Such values are significantly different at the 5-percent level as compared to 100.

[3] Such values are significantly higher at the 1-percent level as compared to 100.

[4] A sodium ferric ethylenediamine tetra-acetate containing 12 percent of metallic iron, known commercially as Sequestrene NaFe.

[5] A relatively insoluble powdered glass containing Mn, Fe, Zn, Cu, B, and Mo, and sold commercially as Ferro FTE.

sucrose contents in stalk and leaf. Liming has proved beneficial on the very acid Pegassy clays of British Guiana (pH below 4).

The question arises in liming sugarcane as to whether the beneficial effect of liming occurs because of a correction of soil pH or because of the calcium added as a needed nutritive plant element. In two of the experiments calcium was added as calcium sulfate (gypsum) rather than as lime ($CaCO_3$). No significant yield responses were obtained (table 1). Unfortunately, the soils tested had pH values of over 6. McGeorge showed that acidity or the H ion by itself had no harmful influence on cane growth in the infertile acid cane soils of mauka fields in Hawaii (12). In the majority of the cases where poor growth was obtained in very acid soils the presence of toxic amounts of aluminum salts retarded growth. Liming in these cases fixed the aluminum in an insoluble form by raising the pH. The authors have seen evidence of aluminum toxicity on the roots of the cane plant in Puerto Rico, growing on a Coloso clay of low acidity (pH 3.8) with poor drainage. This condition was corrected by liming and improving drainage.

It appears that the sugarcane plant is able to obtain sufficient calcium for its needs over a rather wide pH range in Puerto Rico (pH 5.5 to 8). Lime has given some responses to cane yields in soils with a pH below 5.5. At present it cannot be said whether this response is due to the correction of pH or to direct effects of the calcium added. However, in these experiments, it should be remembered that calcium was also added in the form of calcium sulfate in the superphosphate used. Also large quantities of calcium are returned to the soil by the cane trash and roots (16). Hence credit for beneficial effects of liming appears more likely to be due to a correction of very low pH values and the resultant aluminum toxicity rather than to the addition of needed nutritional calcium to the plant.

Boron

The general response of sugarcane to boron fertilization has been variable but rather negligible. In none of the experiments were cane yields increased significantly, and in one experiment (Santa Isabel silty clay, table 1), yields were significantly reduced from the use of 100 pounds of borax per acre. Aside from this one instance rates of up to 100 pounds of borax per acre (11 pounds of boron per acre) did not produce any injurious influence on cane yields in the soils on which they were applied, which were, generally, silty-clay loams to clays. Martín (11) found that although boron deficiencies could be produced in sugarcane growing in nutrient solutions, only 0.22 p.p.m. of boron was needed to prevent this. Borden in Hawaii (3) obtained no yield increase with boron (as boric acid) at 28 and 112 pounds of boron per acre. With 112 pounds of boron per acre a reduced yield was obtained of the H. 32-8560 variety on a makiki soil.

[5] A relatively insoluble powdered glass containing Mn, Fe, Zn, Cu, B, and Mo, and sold commercially as Ferro FTE.

Copper

The response of sugarcane to fertilizers containing copper salts was highly variable. In one case, with a ratoon crop of cane on a San Antón silty clay loam under irrigation, the use of 25 pounds of copper sulfate per acre gave a significant increase in yield. On the other hand, a closely related soil, a Santa Isabel silty clay, also found on the southern coast of Puerto Rico, produced a significant decrease in yield without irrigation when 100 pounds of copper sulfate per acre was used. In both cases, cane tonnages were influenced more than sucrose-percent-cane.

The general response to copper sulfate was low. Although organic soils in New Jersey and Florida have shown favorable responses to copper fertilization, the Tiburones muck, an organic soil of Puerto Rico (table 1) showed no response of sugarcane to copper.

Iron

Of all the minor-element fertilizers used, the highest average increase was produced by the application of iron as ferrous sulfate. In one instance of a first ratoon on a Toa silty-clay loam, 100 pounds of ferrous sulfate per acre gave a very significant increase in sucrose-percent-cane. Applied as a spray, 10 pounds of ferrous sulfate per 100 gallons of water, it also increased yields on a San Antón silty-clay loam, a soil with a pH above 7. The cane plots showed an iron chlorosis in the leaf which disappeared when the iron sulfate was applied. Doty (6) reported improved yields of cane on coral soils of Hawaii where iron sulfate sprays were used. The use of 50 pounds per acre of chelated iron in the soil on a ratoon crop grown on an unirrigated Santa Isabel silty clay (table 1) failed to give yield responses.

Magnesium

On acid soils with a pH below 6, such as Coto clay, Lares clay, or Vía silty clay, magnesium in the form of the oxide gave some yield increases, the average relative yield having been 105. However, no such average increases were found for soils with pH 6 and above. The more soluble magnesium sulfate produced no yield increase. In one instance, on a Coto clay, (table 1), increases were obtained with the less soluble oxide, but not with the more soluble sulfate of magnesium. A significant increase in sucrose-percent-cane, but not in tons of cane, was obtained for the first ratoon. The pattern was just reversed for the second ratoon on the Lares clay. In general, magnesium gave a variable influence on yield.

Manganese

The average response to manganese fertilizers was almost negligible. In only one instance was a significant response obtained. This was for the

plant crop only (12 months) grown on a Coto clay. No significant responses were obtained in the ratoon crops. No response was obtained to manganese fertilizers on the San Antón silty clay loam at Guánica. Preliminary observational experiments in this area 5 years before also failed to show responses.

Sodium

Sodium both as the chloride and sulfate failed to produce any significant increase in sugar per acre on a Toa silty clay loam. The use of sodium sulfate at a rate of 300 pounds per acre reduced yields significantly, although the use of sodium chloride up to 500 pounds per acre gave no detrimental effects. Borden in Hawaii (4) found that sodium as sodium chloride failed to increase potash efficiency. On a low K level sodium chloride lowered Brix and polarization in crusher juice and gave less sugar; and on a high K level, sodium chloride produced no effect on quality or yield.

Sulfur

On soils with a pH above 7, such as San Antón silty clay loam and a Santa Isabel silty clay, the use of sulfur failed to give any increases in yields. The pH values were not appreciably decreased by the sulfur additions for the duration of the experiment.

Zinc

The use of zinc sulfate produced variable results on sugar yields. Some yield responses were obtained on the more acid soils. In one case, a 12-month plant cane on a Coto clay, the yield of available 96° sugar per acre was significantly increased. However, the yield increases were not significant for the ratoons. Even the use of extreme precautions in solution culture failed to produce a zinc deficiency in cane in nutrient studies made in Hawaii (1).

Mixture of elements

The use of a fritted trace-element mixture containing copper, zinc, magnesium, boron, manganese, and iron in the form of relatively insoluble powdered glass failed to give increases in sugar per acre for a Santa Isabel silty clay or a Tiburones muck.

ACEROLA

A very highly significant response has been obtained from the use of lime for acerola on a Sabana Seca sandy clay. The soil, with an original pH of 4.5, gave a relative increase in yield of over 400 percent (see table 2) when 2 tons of lime per acre were added. Chelated iron did not increase yields significantly and the use of fritted trace elements decreased yields.

TABLE 2.—*Range of relative yields obtained with various crops when lime and minor-element fertilizers were applied*[1]

Minor element used	Source	Range of rates used per acre	Relative yield increases per acre where no minor-element fertilizer treatment = 100 for—[2]												
			Acerola	Corn	Cotton	Pepper	Pineapple	Plantain	Sweetpotato	Tobacco	Tomato	Tropical kudzu	Tropical kudzu and Merker grass	Yam	Tanier
		Pounds													
Aluminum	Aluminum sulfate	35	—	—	—	—	100	—	—	—	—	—	—	—	—
Boron	Borax	25–50	—	107	87–106	—	90*[3]	—	105–116*	95	78	83*–100	107	96	92
Calcium	Calcium carbonate	1,000–15,000	410**[4]	—	—	142	100	112	127–150**	106–120*	—	112–120*	—	107	95–144
	Calcium sulfate (gypsum)	500–1000	—	—	—	—	96	—	116*	—	—	—	—	—	—
Copper	Copper sulfate	25–100	—	103	89–101	—	98	—	92	—	—	—	—	—	109
Iron	Chelated iron[5]	100[6]	139	—	—	—	95–112	—	—	—	—	—	—	—	—
	Ferrous sulfate	10[6]	—	—	—	—	115	—	—	—	—	—	—	—	—
Magnesium	Magnesium oxide	50–1,000	—	111	100	—	98	—	110–141**	92–102	73*	94	96	—	—
	Magnesium sulfate (Epsom salts)	300	—	—	100	—	106	—	—	—	—	—	—	—	116
Manganese	Manganese sulfate	25–100	—	123	82–108	—	95	—	90–108	—	—	—	—	—	117
Sulfur	Sulfur	2,000	—	115	—	—	102	—	—	—	—	—	—	—	—
Zinc	Zinc sulfate	35–75	—	102	82–100	—	101	—	—	—	—	—	—	—	71–130
Mixture	Fritted trace elements[7]	100–300	76	—	—	—	111–122*	—	—	—	—	—	—	—	—

[1] All treatments received a complete mixed fertilizer (N—P_2O_5—K_2O).

[2] Where more than one value is given for each treatment, the two values given represent the extremes in relative yields obtained, due to varying rates of application or use in more than one experiment.

[3] Such values are significantly different at the 5-percent level as compared to 100 for the check.

[4] Such values are significantly different at the 1-percent level as compared to 100 for the check.

[5] A sodium ferric ethylenediamine tetra-acetate (12-percent Fe) sold commercially as Sequestrene NaFe.

[6] Applied as a spray using 100 gallons of water mixed with pounds of chemical indicated.

The response to lime in commercial acerola orchards has been noted by the authors. Visual symptoms of calcium deficiency were noted in unlimed acerola trees growing on a Sabana Seca sandy clay (pH 4.2). These symptoms were similar to those developed on calcium-deficient acerolas growing in sand culture in the greenhouse (5). The leaves showed a yellowing at the tips and along the marginal areas. There was a severe burning at the tip of the leaf when the deficiency was more acute.

PINEAPPLE

Iron sprays and a fritted trace-element fertilizer gave relative increases in pineapple yields. The chelated iron source was no better than ferrous sulfate in increasing yields (table 2). The use of fritted trace elements, FTE, a relatively insoluble powdered glass containing manganese, iron, zinc, copper, boron, and molybdenum, did increase yields. It may be that the soil applications of the soluble minor-element fertilizers are leached away before the pineapple plant can make full use of them.

SWEETPOTATO

Borax, lime, gypsum, and magnesium oxide all raised the yields of sweetpotato significantly (9). When used on a Sabana Seca sandy clay, 500 pounds of gypsum per acre increased sweetpotato yields, as did 30 pounds of borax per acre. For the acid Lares clay, raising the soil pH with lime (12,500 pounds per acre) gave a yield increase of 50 percent. Magnesium oxide effects were not consistent. Magnesium oxide raised yields significantly when used at 300 pounds per acre with lime on a Lares clay, but not when 600 pounds per acre were used, nor did it benefit yields at the rate of 200 pounds per acre on a Cataño sandy loam.

TOBACCO

Tobacco gave significant yield increases when lime was applied. The use of 1 ton of lime per acre proved as good as 2 tons on a Juncos clay at Aibonito. Boron or magnesium fertilizers did not increase yields.

TOMATO

Yields of tomato were lowered when 100 pounds of magnesium oxide or 50 pounds of borax per acre were used on a Coto clay at Isabela. The reduction in yield due to the magnesium oxide in this case was significant at the 5-percent level.

TROPICAL KUDZU

Liming gave increased yields of tropical kudzu. On a Fajardo clay at Río Piedras, raising the soil pH from 5.3 to 6.5 with lime increased yields

* Such values are significantly different at the 1-percent level as compared to 100 for the check.
* A sodium ferric ethylenediamine tetra-acetate (12-percent Fe) sold commercially as Sequestrene NaFe.
* A foliar-spray volume 100 gallons of water (with suitable quantities of chemical and material).

of green kudzu forage (10), but not the protein content. At Corozal, on an acid Lares clay (pH 4.5), liming failed to increase kudzu forage production significantly, although the protein contents was significantly increased. The use of 50 pounds of borax per acre reduced yields significantly when applied to the unlimed soil. There was no appreciable yield reduction when borax was used with lime. There was no marked response to magnesium fertilizers for kudzu.

GRAPEFRUIT

The application of zinc and magnesium sulfate as spray and in the soil relieved grapefruit trees from visual symptoms of deficiency of the above-mentioned minor elements. The observations were made at Arecibo on an old grapefruit orchard planted on Sabana Seca sandy clay. The use of the magnesium and zinc sprays corrected a heavy shedding of the leaves on these grapefruit trees.

CROPS SHOWING NO RESPONSE

Corn showed no significant response to minor-element fertilizers when grown on an unirrigated Santa Isabel silty clay at Lajas (table 2).

No significant responses were obtained from the use of minor-element fertilizers on cotton growing in a Coto clay at Isabela (pH 6.5) (table 2).

Liming at the rate of 1 ton per acre failed to give a significant yield increase for peppers when grown on a Juncos clay at Aibonito.

Liming failed to increase the yields of plantain on a Lares clay. Original soil pH was 4.6, and sufficient lime was added to raise the pH to 6.2.

When grown in a mixed stand, tropical kudzu and Merker grass did not respond significantly to boron or magnesium applications on a Fajardo clay at Río Piedras (15).

Neither liming nor borax produced any significant increase in yields of yam (*Dioscorea rotundata*) when grown on a Lares clay at Utuado.

On an acid Lares clay at Corozal, lime alone or in combination with zinc, magnesium, copper, or magnesium salts failed to increase yields significantly for taniers (*Xanthosoma atrovirens*).

SUMMARY

The effects of lime and minor-element fertilizers on the yield of sugarcane, root crops, legumes, vegetables, cotton, corn, pineapple, and acerola covering different soil types and climatic conditions, were investigated and the following conclusions were drawn from the results:

1. The use of lime on acid soils (pH below 5.5) increased yields for the majority of the crops studied.

2. No response was obtained on the yield of sugarcane with the use of lime on soils with a pH above 6.

3. The yield of acerola was increased over 400 percent when lime was applied to a Sabana Seca sandy clay soil (pH 4.5).

4. In general, no consistant yield increases were obtained from the use of manganese sulfate, sodium chloride, sulfur, zinc sulfate, mixtures of minor elements, magnesium oxide, and borax, with the exception of the last two, which gave significant yield increases of sweetpotatoes, when used on a Lares clay and Sabana Seca sandy clay.

5. The use of iron sprays and fritted trace elements gave increases in pineapple yields. Ferrous sulfate and chelated iron proved to be equally effective.

6. Crops showing no response were corn, cotton, peppers, plantains, tropical kudzu and Merker in a mixed stand, yams (*Dioscorea rotundata*), and taniers (*Xanthosoma atrovirens*).

RESUMEN

Los resultados de las investigaciones, llevadas a cabo en distintos tipos de suelos y condiciones de clima, para determinar los efectos de las aplicaciones de cal y elementos menores sobre el rendimiento de la caña de azúcar, y sobre la producción de tubérculos, leguminosas, hortalizas, algodón, maíz, piña y acerola, han motivado las conclusiones siguientes:

1. Los rendimientos de la mayoría de las cosechas bajo estudio aumentaron cuando se usó el carbonato de calcio en aquellos suelos ácidos con un pH menor de 5.5.

2. La aplicación del carbonato de calcio a suelos de un pH de 6 ó más, no tuvo efecto significativo sobre los rendimientos de la caña de azúcar.

3. La producción de acerolas aumentó un 400 por ciento en la arcilla arenosa Sabana Seca (pH 4.5), cuando se aplicó carbonato de calcio.

4. En general, los resultados no indicaron aumentos continuos mediante el uso de sulfato de manganeso y zinc, cloruro de sodio, azufre, compuestos de elementos menores, óxido de magnesio y borax, con la excepción de estos dos últimos, los cuales aumentaron significativamente los rendimientos de la batata cuando se aplicaron a la arcilla Lares y a la arcilla arenosa Sabana Seca.

5. Los rendimientos de la piña aumentaron mediante las aspersiones de hierro y la aplicación de elementos menores (fritted-trace elements). El sulfato de hierro y el hierro quelado probaron ser igualmente eficaces.

6. Las cosechas que no respondieron a los tratamientos fueron: Maíz, algodón, pimiento, plátano, kudzú trópical y yerba Merker en siembra mixta, ñame (*Dioscorea rotundata*), y yautía. (*Xanthosoma atrovivens*).

LITERATURE CITED

1. Anonymous, Experiment Station Committee Report 1954, Hawaiian Sugar Planters' Assoc. p. 11, 1954.
2. Baver, L. D., Report of Committee in charge of the Experiment Station, Hawaiian Sugar Planters' Assoc., p. 44, 1948.
3. Borden, R. J., The effects of boron on sugarcane, Experiment Station Committee Report of 1944 Hawaiian Sugar Planters' Association p. 51, 1944.
4. ——, Sodium chloride on 32–8560 cane, Experiment Station Committee Report of 1945, Hawaiian Sugar Planters' Association, pp. 48–9, 1945.
5. Cibes, H., and Samuels, G., Mineral deficiencies in acerola trees, Agricultural Experiment Station, University of Puerto Rico, Technical Paper 14, 1956.
6. Doty, R. E., Iron sulfate spray for coral chlorosis, *Hawaiian Planters' Rec.* 34 79–82, 1930.
7. ——, The effect of lime applications on juice quality, *Hawaiian Planters' Rec.* 39 326–32, 1935.
8. Hopkins, E. F., Pagán, V., and Ramírez-Silva, F. J., Iron and manganese in relation to plant growth and their importance in Puerto Rico, *J. Agr. Univ. P. R.* 28 43–101, 1944.
9. Landrau, P., Jr., and Samuels, G., The effect of fertilizers on the yield and quality of sweetpotatoes, *J. Agr. Univ. P. R.* 35 (2) 71–86, 1951.
10. Landrau, P., Jr., Samuels, G., and Rodríguez, J. P., Influence of fertilizer minor elements, and soil pH on the growth and protein content of tropical kudzu, *J. Agr. Univ. P. R.* 37 (1) 81–95, 1953.
11. Martin, J. P., Boron deficiency symptoms in sugarcane, *Hawaiian Planters' Rec.* 38 95–107, 1934.
12. McGeorge, W. T., The influence of aluminum, manganese, and iron salts upon the growth of sugarcane, and their relation to the infertility of acid Island soils, Hawaiian Sugar Planters' Assoc. Exp. Station, Agr. and Chem. Series Bul. 49, 1–92, July 1925.
13. Pennock, W., Field response of red spanish pineapples to nitrogen, calcium, iron, and soil pH, *J. Agr. Univ. P. R.* 33 1–26, 1949.
14. Ramírez-Silva, F. J., The effect of certain micronutrient elements on the growth and yield of pineapple plants, *J. Agr. Univ. P. R.* 30 197–250, 1946.
15. Samuels, G., and Landrau, P., Jr., Potassium competition in a kudzu-Merker grass association, *J. Agr. Univ. P. R.* 38 (4) 273–382, 1953.
16. ——, The effect of differential sugarcane fertilizer treatment on a Coloso silty clay, *J. Agr. Univ. P. R.* 38 179–87, 1954.
17. Schappelle, N. A., The effect of pH and of certain minor elements on the growth of pineapples in water cultures, *J. Agr. Univ. P. R.* 26 (3) 63–72, 1942.

Effects of Tractor-Traffic Compaction on the Physical Properties of an Irrigated Soil in Southwestern Puerto Rico

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INTRODUCTION

Problems associated with soil-packing or compaction by tractor wheels or tracks have been a topic of discussion since the advent of the tractor. In fact, almost any new type of equipment developed is claimed to be capable of producing greater traction with less packing. The U. S. Department of Agriculture has conducted some work along this line, mainly at its Tillage Machinery Laboratory at Auburn, Ala. State experiment stations have shown some interest in this problem too, (2, 8, 9, 12).[2] European workers have also given attention to the problems associated with soil compaction (1). No such studies have been conducted in Puerto Rico, the chief reason being that the Island's agriculture is not yet highly mechanized. However, progress in sugarcane mechanization, although slow, has accelerated lately (figs. 1 and 2). Marked mechanical advances have been made also in corn (fig. 3) and sweetpotato (fig. 4) cultivation. Such achievements in mechanized farming are likely to continue at a gradual, but steady pace, so that agricultural progress can maintain a highly competitive and commercial basis.

With increasing use of heavy equipment on the farm the problems associated with soil compaction will be of considerable importance. Soil-structure deterioration is likely to occur. Water movement, aereation, and root development will be adversely affected, particularly in soils having a wide range of particle sizes such as loams (5). A survey in other areas has led to the conclusion that there is no easy, rapid, and economic solution to the compaction problem (3). The best approach seems to lie in minimizing soil compaction through the use of intelligent soil-management practices and techniques.

OBJECTIVES

The study reported herein presents preliminary information as to the possible immediate effects of heavy tractor traffic on an irrigated soil in southwestern Puerto Rico. It must be admitted at the outset that the results reported barely scratch the surface of this potential problem. This report

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[2] Numbers in parentheses refer to Literature Cited, pp. 243–4.

FIG. 1.—Cane-harvesting equipment in trial operation in southern Puerto Rico.

FIG. 2.—The application of fertilizer through mechanical means is becoming increasingly popular among sugarcane growers.

FIG. 3.—Pregermination treatment of corn fields for weed control. This photo was taken on a training field day at the Lajas Agricultural Experiment Substation.

is intended as a warning about the possible harmful effects on soils of very essential and otherwise beneficial mechanization. Most of the investigators working on these problems have been limited to the use of bulk-density changes as indices of soil compaction. They are indeed good indices, probably the best. This paper, however, in addition to measurements of bulk-density changes, reports effects of soil compaction on the water movement and water-retention power of the soil. The data are very revealing, and it is hoped that they will open up new avenues of research looking toward a more rounded and complete understanding of the compaction problem in soils.

MATERIALS AND METHODS

Preliminary compaction studies were made on soil samples taken from a longtime fertilizer experimental field of 5-acres used to grow sugarcane at Hacienda María Antonia in southwestern semiarid Puerto Rico. This field had been in sugarcane for many years prior to establishing the experiment. The soil was classified as Vayas clay, a poorly drained soil of the river flood plains. It is deep, very fertile, and occupies nearly level areas near stream channels. At the surface it is of a dark grayish-brown color, with a rather well-developed structure. Aggregates are predominantly small, ranging

FIG. 4.—Sweetpotato-harvesting equipment in operation during another training field day at one of the Station farms.

from subangular to almost rounded, and are rather loosely packed. Beginning at a depth of 20 or 30 inches this soil becomes mottled-gray or rust-brown, and the structure is rather weakly developed with somewhat densely packed medium-large aggregates.

Undisturbed soil-core samples (3″ x 3″) were taken from adjoining rows some 3 weeks after harvesting the thirteenth consecutive sugarcane crop within the sequence of the long-range fertilizer experiment. One row had been traversed recently by a heavy tractor pulling numerous 3-ton cane-loaded steel cars, including the whole crop from the 5-acre field (fig. 5), while the adjoining row was not affected by this traffic. The cane shoots of the following ratoon crop from the tractor-compacted row developed weakly and needed extensive replanting. In the adjoining unaffected rows the

FIG. 5.—Closeup of tire-tractor impressions on moist soil.

ratoon canes developed rather vigorously. The cores were taken from five different plots along the 160-foot-wide field, by using an Uhland sampler, both at 0-3-inch and 4-7-inch depths from each of adjacent rows, 4 feet apart. The number of blows required to take each core was recorded, and the work in sampling was calculated by multiplying the weight of the hammer of the sampler by the length of the handlebar through which the hammer slid. In addition, a bulk composite soil sample was taken from the five plots where cores were obtained.

Hydraulic-conductivity measurements were made by recording the rate at which water moved through a column of saturated soil at a known head. Quick drainage was determined by placing the saturated soil core on a Büchner funnel at a 60-cm. tension and measuring the water drained out in 15 minutes. Water removed and retained at pF 1.78 was measured by bringing the soil core to equilibrium in a 60-cm. tension table. The soil core was finally dried at 110°C. As the samplers used were of a known volume, the bulk density of the soil was calculatd by dividing the net dry weight of the soil by its original volume. The pore space was then calculated by assuming a specific gravity of 2.65.

The pH of the composite sample was determined electrometrically by means of a Macbeth pH-meter. Organic matter was determined by the chromic acid titration method. The mechanical composition of the soil was

determined by the pipette method, centrifuging instead of filtering through a Chamberlain-Pasteur filter.

RESULTS AND DISCUSSION

The following tabulation gives data on the mechanical composition of the soil and its organic-matter content:

Constituent	*Percent*
Sand	35.5
Silt	20.2
Clay	44.3
Organic matter	2.8

The clay content of the soil is rather high as is the case with most of the alluvial soils of the valleys in southwestern Puerto Rico. The soil is alkaline (pH 8.0) with a moderately high level of organic matter.

Table 1 gives data on the immediate effect of heavy tractor traffic on some of the physical properties of this poorly drained soil. The reduction in quick drainage (water drained at 60-cm. tension in 15 minutes) with compaction is outstanding, the mean differences being significant at the 0-3-inch depth. This difference indicates restricted water movement in saturated clayey soils immediately after trampling by heavy-tractor traffic. Differences in bulk-density values between the soil subjected to heavy traffic and the untrampled soils are highly significant in the surface 3-inch layer and significant in the lower (4-7-inch) layer. The trampled soils are much denser, of course.

Data were taken as to the work required to take core samples from compacted and undisturbed soils. The mean differences are highly significant at both sampling depths. As shown in table 1 more work was required to sample the compacted soils. These could be related to the differences in work that would be required to carry on land preparation and cultivation operations in compacted and noncompacted soils. Measurements as to the draft required in both cases might be very revealing. Prevention of soil compaction might save considerable farm power.

There were highly significant and significant reductions in total pore space at the 0-3-inch and 4-7-inch depths, respectively, as indicated by the porosity values in table 1. Highly significant differences were measured at both depths in relation to the percentage of pores drained at low tensions such as those that develop in the vicinity of pF 1.78. However, water retention at such low tensions was not affected. This behavior indicates that, although there was a marked reduction in total pores, the micropores remained unaffected, the reduction thus being in the range of large pores (those that hold water at tensions lower than pF 1.78). Such a reduction

TABLE 1.—*Immediate effect of heavy-tractor traffic on some physical properties of an irrigated soil in southwestern Puerto Rico*

Soil condition	Depth	Hydraulic conductivity	Water drained in 15 minutes at 60-cm. tension	Bulk density	Work required in sampling 3″ x 3″ cores	Porosity	Water removed at pF 1.78	Water retained at pF 1.78
	Inches	*In./hr.*	*Percent*	*Gm./cc.*	*Ft.-lb.*	*Percent*	*Percent*	*Percent*
Compacted by heavy-tractor traffic	0–3	0.046	1.66	1.33	808.63	49.66	1.28	51.13
Not affected by heavy-tractor traffic	0–3	.335	6.20[1]	1.14[1]	665.69[1]	56.96[1]	3.82[1]	51.37
Compacted by heavy-tractor traffic	4–7	.022	1.37	1.39	845.39	47.40	.96	50.19
Not affected by heavy-tractor traffic	4–7	.090	3.04	1.30[2]	698.36[1]	51.02[2]	2.84[1]	51.67
L.S.D. for 2 treatments at the same depth:								
At the 5-percent level		.998	3.12	.09	30.63	3.45	.99	4.15
At the 1-percent level		1.590	5.02	.14	45.13	5.24	1.51	6.48

[1] Highly significant difference between the value thus identified and the one above it in the same column.

[2] Significant difference between the value thus identified and the one above it in the same column.

in the macropores largely explains the reduction in drainage and aeration associated with increased compaction.

The preliminary work herein reported is limited to the measurements of some compaction indices in the uppermost 7 inches of soil. There is evidence from research in other areas (10, 14) that annual tractor traffic in itself is capable of compacting soils to lower depths, even to depths of 24 inches, *i.e.*, well below the reach of normal land preparation and cultivation operations when soil-moisture levels approximate the optimum moisture for tillage. Therefore, the tractor must be considered as a major contributing factor in inducing traffic soles or hardpans.

Free, *et al.*, (4) found a definite relationship between the organic-matter level of a soil and its degree of compactability. Furthermore, in truck-crop areas in Long Island, N. Y., it has been found (16, 13) that there was a higher soil density in the spray-wheel middle than in the nonwheel middle, but

the compaction was lessened with increased organic-matter levels. The continuous additions of organic residues in the form of trash and roots to sugarcane fields in Puerto Rico must be a factor in reducing compaction.

It might be well to recall at this time that it is of importance to recognize and carefully separate and define the different field situations that might be ordinarily considered as compaction problems.[3] There are genetically developed compacted layers and traffic-induced (implement traffic, tillage operations, and livestock trampling) pans. Studies to improve structural conditions in heavy claypan soils have been conducted locally (7). The following tabulation shows the effect of deep tillage on the infiltration rate of a genetically compacted soil in east-central Puerto Rico:

Treatment	*Eighth-hour infiltration rate in./hr.*
Undisturbed soil	0.5
Ordinary plowing and harrowing (4 times)	5.6
Subsoiling	26.7

The infiltration capacity of this soil was increased tenfold by ordinary plowing and harrowing only. Digging down around the borders of the wetted area disclosed that most of the water entering the soil of the plowed and harrowed plots through the immediate surface moved laterally after reaching the claypan, rather than downward in the profile. Where the claypan was shattered by the subsoil standard the water moved downward through the disturbed layer (7).

Deep tillage might prove as effective in breaking induced pans as with genetically indurated layers. There is need for more extensive information concerning the probable impact of farm mechanization on soil properties. It is a problem challenging soil scientists and agricultural engineers as well. Much remains to be done in recognizing situations under field conditions, analyzing the factors responsible for such conditions, as well as the soil properties affected, and developing both preventive and corrective measures as well.

SUMMARY

A short discussion on the effect of heavy traffic on soil physical properties is presented. Soil cores were taken at 0-3- and 4-7-inch depths from rows of plots trampled by heavy tractor traffic and also from adjacent untrampled rows. The following physical properties were investigated: Bulk density, hydraulic conductivity, quick drainage, maximum saturation, total porosity, and water removal and retention at pF 1.78. Quick-drainage values indicated compaction due to tractor tires. The soil in the rows sub-

[3] Raney, W. A., *et al.*, (11) present a good discussion on the necessity of recognizing different kinds of conditions restricting root penetration.

jected to heavy traffic was denser, required more effort to sample, and its porosity was reduced somewhat, but water retention at low tensions was not affected.

The possibilities of deep tillage as a corrective measure are indicated, but stress is given to the development of sound preventive soil-management techniques.

RESUMEN

Se discute brevemente el efecto de tránsito de vehículos pesados sobre las propiedades físicas del suelo. Se tomaron cilindros de suelo a profundidades de 0–3″ y 4–7″ en hileras de parcelas sometidas al tránsito de vehículos pesados y en hileras adyacentes que no sufrieron los efectos del tránsito. Se investigaron las siguientes propiedades del suelo: Densidad aparente, conductividad hidráulica, desagüe rápido, saturación máxima, porosidad total y remoción y retención de humedad a pF 1.78. La medida de desagüe rápido indicó que el suelo en las hileras sometidas al tránsito pesado era mucho más compacto. También este suelo resultó ser mucho más denso y su porosidad se redujo, pero su habilidad de retener humedad a tensiones bajas no se afectó.

Se menciona la posibilidad de corregir esta situación por medio de labranzas profundas, pero se da énfasis a la necesidad de dar preferencia al desarrollo de técnicas de manipulación del suelo de naturaleza preventiva.

LITERATURE CITED

1. Brind, W. D., Some German and Austrian work on soil compaction and fertility, *Soils and Fert.* **15** (4) 227–30, 1952.
2. Bruce, R. R., An instrument for determining soil compactability, *Soil Sci. Soc. Amer. Proc.* **19** (3) 253–7, 1955.
3. Doneen, L. D., and Henderson, D. W., Compaction of irrigated soils by tractors, *Agr. Eng.* **34** (2) 94–5, 102, 1953.
4. Free, G. R., Lamb, J., Jr., and Carleton, E. A., Compactability of certain soils as related to organic matter and erosion, *J. Amer. Soc. Agron.* **39** (12) 1068–76, 1947.
5. Huberty, M. R., Compaction in cultivated soils, *Trans. Amer. Geophys. Union* **25** 896–9, 1944.
6. Klute, A. and Jacob, W. C., Physical properties of Sassafras silt loam as affected by long time organic matter additions, *Soil Sci. Soc. Amer. Proc.* **14** (1) 24–8, 1949.
7. Martínez, M. B., and Lugo-López, M. A., Influence of subsoil shattering and fertilization on sugarcane production and soil infiltration capacity, *Soil Sci.* **75** (4) 307–15, 1953.
8. McKibben, E. G., and Green, R. L., Transport wheels for agricultural machines VII, Relative effects of steel wheels and pneumatic tires on agricultural soils, *Agr. Eng.* **21** (5) 183–5, 1940.
9. Nichols, M. L., Cooper, A. W., and Reaves, C. A., Design and use of machinery to loosen compact soil, *Soil Sci. Soc. Amer. Proc.* **19** (2) 128–30, 1955.

10. Parker, E. R., and Jenny, H., Water infiltration and related soil properties as affected by cultivation and organic fertilization, *Soil Sci.* **60** (5) 353–76, 1945.
11. Raney, W. A., Edminster, T. W., and Allaway, W. H., Current status of research in soil compaction, *Soil Sci. Soc. Amer. Proc.* **19** (4) 423–8, 1955.
12. Reed, I. F., A method of studying soil packing by tractors, *Agr. Eng.* **21** (7) 281–2, 285, 1940.
13. Russell, M. B., Klute, A., and Jacob, W. C., Further studies on the effect of long time organic additions on the physical properties of Sassafras silt loam, *Soil Sci. Soc. Amer. Proc.* **16** (2) 156–9, 1952.
14. Weaver, H. A., Tractor use effects on volume weight of Davidson loam, *Agr. Eng.* **31** (4) 182–3, 1950.

The Use of Chelates to Control Iron Chlorosis in Soybeans Grown in Alkaline Substrate Under Greenhouse Conditions

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INTRODUCTION

It is often observed that iron chlorosis develops in plants grown under greenhouse conditions in sand or water cultures. This situation is frequently attributable to the precipitation of iron by phosphates when they are used in relatively high concentrations or in nutrient solutions with pH values above 6.

Though the maintenance of adequate iron for greenhouse plants might be a problem, it is not as serious as with plants grown under field conditions because of the complexity of the soil problems involved. Iron chlorosis is of common occurrence in the citrus-growing sections of Florida, both on the alkaline soils of the East Coast and in acid soils elsewhere (9, 10, 11).[2] It is also prevalent in the northwestern States where it is induced by high soil alkalinity. In Hawaii and Puerto Rico (3, 5, 6, 7) iron chlorosis has been reported to be caused by high manganese concentration in the soil. Excessive use of soil phosphorus (2) may be a factor responsible for lack of iron in plants. Thus, it is apparent that the problem of iron-induced chlorosis is of importance in some agricultural areas.

During the past few years attention has been given to the use of the new iron compound commonly known as iron sequestrene as a feasible way of correcting iron deficiency in tree fruits and other crops. This compound is a complex form of iron made up by combining salts of ethylenediamine tetraacetic acid (EDTA) with iron, thus forming a very stable iron complex. It is believed this iron complex is rendered available to the plant without being broken down in the soil (9, 10, 11). These organic compounds which combine with iron or any other metals are commonly called chelating agents. This paper reports on the results of tests conducted under greenhouse conditions to determine the effectiveness of a chelate compound (NaFe sequestrene) in controlling iron chlorosis in soybean plants grown in an alkaline substrate.

REVIEW OF LITERATURE

The literature dealing with the use of iron sequestrene or chelated iron in experimental work is rather scant. Iron chlorosis in fruit trees has been

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[2] Numbers in parentheses refer to Literature Cited, p. 254.

controlled by using chelated iron. Stewart and Leonard (9, 10, 11) working in Florida corrected iron chlorosis in orange trees by applying chelated iron to an acid soil at the rate of 10 to 20 gm. in solution around the trees. Trees became green about 6 weeks after the organic compound was applied. Results on calcareous soils indicated that higher rates of application of the compound were required. Iron deficiency has also been controlled by using EDTA in the soil without supplementing it with iron. The authors point out that probably the iron in the soil was chelated by the added sequestrene. Chemical analyses for total iron in the leaves of the new spring growth of orange trees which received chelated iron was found to be almost twice that found in leaves from nearby untreated trees, or in leaves treated with 15 pounds of iron sulfate.

Jacobson (4) has demonstrated that the iron supply in the nutrient solution can be maintained by using ferric potassium ethylenediamine tetraacetate. He found that nutrient solutions containing 5 or 10 p.p.m. of iron provided adequate iron to such plants as tomatoes, corn, barley, and sunflower.

As mentioned by Alexander and Walsh (1), sequestrene, in combination with iron, maintains iron in solution so that a substantial amount would be available for plant assimilation in but a single application, whereas multiple applications of iron citrate would be required to achieve comparable results. The authors suggest that applications of the iron complex as a spray to the leaves of chlorotic plants is also promising in correcting iron-induced chlorosis.

Samuels and Cibes (8) obtained satisfactory control of iron chlorosis on *Dracaena sanderiana*, under greenhouse condition, by using Fe-EDTA sprays (1 pound per 100 gallons). They reported that ferrous sulfate sprays were not effective.

MATERIAL AND METHODS

CULTURAL METHODS

Seeds of soybeans, variety Lincoln, selected for uniformity in size were soaked in distilled water for about 2 hours. After this they were transferred to moist filter paper in petri dishes and incubated at a temperature of 33°C. After germination and when the hypocotyls were about 3 to 4 cm. in length, the germinated seeds with seedcoats removed were transferred to a paraffined cloth net stretched tightly over a pan containing a dilute nutrient solution. At the end of 10 days the best seedlings were selected and transferred to the culture jars. First, the seedlings received a complete nutrient solution of similar composition to one of the solutions used later in the experiment, but at one-half strength. Trace elements including iron

were supplied too. At the end of about a week, differential nutrient treatments were started and maintained for 21 days.

There were 12 cultures which were divided into two groups of 6 cultures each. One group of cultures was grown in a complete nutrient solution with pH adjusted to 5, while the second group was grown in a nutrient solution with pH adjusted to 7. The pH of the nutrient solutions was adjusted to the desired value by varying the concentrations of potassium sulfate and substituting the monopotassium acid phosphate by dipotassium acid phosphate where a pH of 7 was required. The composition of the nutrient solutions in molar concentrations, to which the plants were subjected is shown in the following tabulation:

$Ca(NO_3)_2$	0.005
K_2SO_4	.002
KH_2PO_4	.001
$MgSO_4$	.002

The treatments at each pH level were as follows:

Culture	*Treatment*
1	0.5 p.p.m. inorganic iron as iron sulfate
2	.01 p.p.m. iron as iron sequestrene
3	.5 p.p.m. iron as iron sequestrene

Only 0.0015 M K_2SO_4 with K_2HPO_4, instead of the KH_2PO_4, was used in cultures requiring pH 7, as mentioned previously. Trace elements were supplied, expressed in parts per million as follows: B 0.1, Mn 0.005 or 0.25, Mo 0.01, Cu. 0.01, and Zn 0.002. The ratio of iron to manganese was kept at 2:1.

Plants in the various treatments were harvested 3 weeks after the treatment differentials were set. The tops were sectioned from the roots and weighed. The uppermost leaves and buds of each plant were then removed and rinsed in distilled water. Then they were blotted with absorbent paper and weights were recorded. Next, the tissue was divided into two portions, one of which was immediately frozen in a deep freezer while the other portion was dried. This was necessary in order to determine the total and soluble iron and manganese content of the leaf tissue desired.

ANALYTICAL METHODS

For determining the soluble iron and manganese the frozen-tissue samples were thawed and wrapped in a piece of muslin, and then placed in an aluminum cylinder and subjected to a pressure of 2,000 pounds per square inch for three consecutive periods in a Carver press, each period of extraction amounting to 1 minute. About 5 cc. of distilled water was added to

each sample at each period to aid in the extraction of the cell sap. The press cake obtained was weighed after drying and was used for the determination of iron and manganese. Soluble iron and manganese of the tissue were determined by the difference between the analytical values of these two elements in the unextracted sample and the extracted press cake. Thus, it is assumed here that the juices extracted by pressure contained the soluble part of iron and manganese, while those remaining in the press cake were considered to be the inactive or insoluble iron and manganese.

The procedure used by Toth *et al.* (12) was followed for the determination of iron and manganese in the leaf samples. Iron was determined colorimetrically as the ferrous orthophenanthroline complex. Manganese was determined colorimetrically as the permanganic acid after oxidation with periodate.

RESULTS AND DISCUSSION

EFFECT OF TREATMENT ON PLANT GROWTH

Figure 1 shows the response of the soybean plants to the different treatments. During the course of the experiment it was observed that plants which were grown in the nutrient solution maintained at pH 5 and which received 0.5 p.p.m. iron as iron sulfate, or 0.5 p.p.m. as iron sequestrene, developed normally. No evidence of chlorosis was observed in these plants which indicated that the iron supply was sufficient for their metabolic proc-

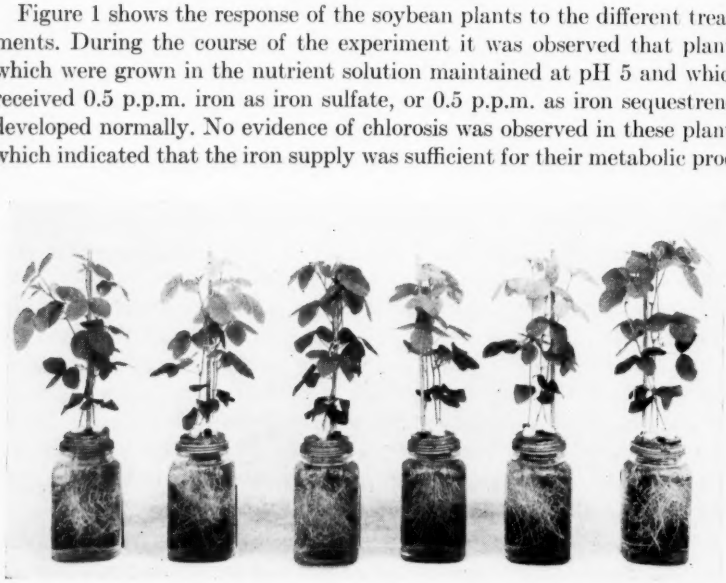

FIG. 1.—Degree of iron chlorosis in soybean plants at pH 5: Culture 1, 0.5 p.p.m. iron as iron sulfate; culture 2, 0.01 p.p.m. chelated iron; culture 3, 0.5 p.p.m. chelated iron. At pH 7: Culture 1, 0.5 p.p.m. iron as iron sulfate; culture 2, 0.01 p.p.m. chelated iron; culture 3, 0.5 p.p.m. chelated iron.

esses (cultures 1, 3). On the other hand, the plants supplied with 0.01 p.p.m. iron as iron sequestrene (culture 2) developed a chlorosis in the newly formed leaves as well as in the next youngest leaves. Leaves were yellow and somewhat crinkled with many tiny brownish spots scattered on the surface. This indicated that the iron supplied in the nutrient solution, although in the chelated form, was insufficient to supply the plants with an adequate quantity and therefore iron-induced chlorosis developed.

Observations made on the plants grown in the nutrient solution maintained at pH 7 revealed rather interesting facts. Those plants which received 0.5 p.p.m. iron as iron sulfate had yellow tops and tiny brown spots, and had crinkled and cup-shaped leaves (culture 1). On the other hand, the plants that received 0.5 p.p.m. of iron as iron sequestrene did not show any evidence of iron chlorosis (culture 3). They were healthy and green throughout the duration of the experiment. This indicates that iron was apparently taken by the roots freely from the chelate form, and not from the iron sulfate, in sufficient quantity to satisfy the needs of the plants at this high pH level. Probably at pH 7 most of the iron in the sulfate form precipitated as insoluble iron phosphate and therefore was insufficient for root absorption.

Plants which received 0.01 p.p.m. of chelated iron were quite chlorotic and had crinkled, and cup-shaped leaves with necrotic spots scattered over the leaf surface (culture 2). This last group of plants grown at pH 7, were much more chlorotic than plants grown at pH 5 with same level of iron sequestrene.

EFFECT OF TREATMENTS ON FRESH AND DRY WEIGHT OF TOPS AND ROOTS

Table 1 presents the results obtained as to fresh and dry weights of the tops and roots of the plants, including the calculated top/root ratios.

It can be seen that plants grown in the nutrient solution maintained at pH 5 and which received 0.5 p.p.m. of iron in the chelated form (culture 3) surpassed the plants in other treatments in fresh and dry weights of tops as well as in fresh and dry weights of roots, but differences at this pH level were not significant.

When considering the results obtained from plants under the same treatments at pH of 7, it is also evident that those which received 0.5 p.p.m. of chelated iron (culture 3) surpassed plants in other treatments in the various criteria considered, but were only significantly superior with respect to green and dry weight of tops. Percentage differences as high as 20 or 25 were obtained for green and dry weights of plants grown with 0.5 p.p.m. of chelated iron as compared to those receiving 0.01 p.p.m. of chelated iron or 0.5 p.p.m. of iron as iron sulfate.

TABLE 1.—*Fresh and dry weights of tops and roots of soybean plants grown under the various treatments*

pH and culture No.	Treatment	Fresh weight of tops	Dry weight of tops	Fresh weight of roots	Dry weight of roots	Ratio, top/root
		Gm.	*Gm.*	*Gm.*	*Gm.*	
pH 5:						
1	0.5 p.p.m. inorganic iron as iron sulfate	20.25	2.25	5.5	0.43	5.23
2	Iron sequestrene containing 0.01 p.p.m. iron	19.50	2.25	6.4	.46	4.89
3	Iron sequestrene containing 0.5 p.p.m. iron	21.25	2.36	6.9	.48	4.92
pH 7:						
1	0.5 p.p.m. inorganic iron as iron sulfate	20.45	2.27	7.7	.51	4.45
2	Iron sequestrene containing 0.01 p.p.m. iron	19.45	2.19	7.9	.50	4.38
3	Iron sequestrene containing 0.5 p.p.m. iron	24.35	2.74	8.6	.56	4.89
L.S.D. (0.05) between two culture means for same pH level		3.03	0.42	1.63	0.14	

CHEMICAL ANALYSES

The results of the chemical determinations for total and soluble iron and manganese of the upper leaves of the plants which underwent the various treatments are presented in table 2.

From the results obtained on total and soluble iron in the upper leaves of plants grown in the nutrient solution maintained at pH 5, it seems that soluble iron is related to the total iron content of the tissue which, in turn, appears to be determined by the iron concentration of the substrate. Thus total and soluble iron were least for plants of culture 2 (0.01 p.p.m. of chelated iron in the substrate) and higher for plants of cultures 1 and 3 which contained 0.5 p.p.m. of iron, either chelated or nonchelated, in the nutrient medium.

It is of interest to note that the soluble-iron content of the upper leaves of the plants which received 0.5 p.p.m. of iron in the chelated and in the inorganic form was practically the same (cultures 1 and 3). These were the plants which did not show any sign of chlorosis when grown at pH 5 (fig. 1). Thus, at pH 5, 0.5 p.p.m. of inorganic iron as iron sulfate was as effective as 0.5 p.p.m. of chelated iron in maintaining the plants in a healthy condition. However, 0.01 p.p.m. of chelated iron was insufficient to keep plants growing normally.

TABLE 2.—*Results of chemical analyses for total as well as soluble iron and manganese of the upper leaves of soybean plants grown under the various treatments*[1]

pH and culture No.	Treatment	Total Fe	Soluble Fe	Soluble Fe in total	Total Mn	Soluble Mn	Soluble Mn in total
		P.p.m.	*P.p.m.*	*Percent*	*P.p.m.*	*P.p.m.*	*Percent*
pH 5:							
1	0.5 p.p.m. inorganic iron as iron sulfate	148.32	41.07	27.6	82.50	29.22	35.4
2	Iron sequestrene containing 0.01 p.p.m. iron	111.13	21.10	18.9	16.50	9.84	59.6
3	Iron sequestrene containing 0.5 p.p.m. iron	150.94	42.06	27.8	75.00	27.63	36.8
pH 7:							
1	0.5 p.p.m. inorganic iron as iron sulfate	121.22	13.93	10.7	74.25	20.97	28.2
2	Iron sequestrene containing 0.01 p.p.m. iron	98.75	12.99	14.1	13.20	6.21	47.0
3	Iron sequestrene containing 0.5 p.p.m. iron	162.50	49.72	30.6	65.00	25.04	38.5
L.S.D. (0.05) between 2 culture means for same pH level		2.67	2.19		5.63	3.75	
L.S.D. (0.01) between 2 culture means for same pH level		4.43	3.63		9.33	6.22	

[1] The ratio of iron to manganese in the nutrient solution at any given treatment was kept at 2:1

The upper leaves of plants grown in solutions at pH 7 at the lowest concentration of iron (0.01 p.p.m. of chelated iron) had the lowest total and soluble-iron content. It can be seen that both the total and the soluble iron of these plants were reduced more at the higher than at the lower pH of the nutrient solution. The same was true for the plants which were supplied with 0.5 p.p.m. of inorganic iron as iron sulfate (culture 1). On the other hand, plants supplied with 0.5 p.p.m. of chelated iron in the nutrient solution had the highest total- and soluble-iron contents in their upper leaves. Thus, from the results obtained on iron content of the upper leaves of plants grown at pH 7, it is evident that the two lowest soluble-iron contents were associated with iron chlorosis while highest was associated with healthy plants. Under the conditions of this experiment the use of iron sequestrene containing 0.5 p.p.m. of iron was enough to maintain soybean plants healthy at pH 7 without any sign of chlorosis. Figure 2 illustrates graphically the soluble-iron content of the upper leaves of plants under the various treatments.

Table 2 further shows that, at either pH 5 or 7, the total and soluble

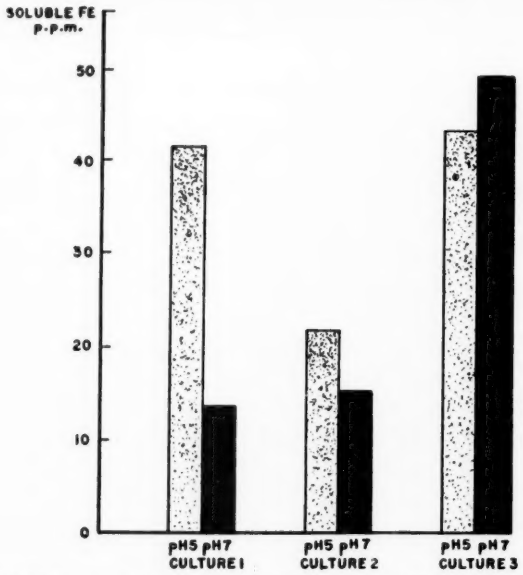

FIG. 2.—Soluble-iron content of the top leaves of soybean plants grown at two pH levels: Culture 1, plants grown with 0.5 p.p.m. of inorganic iron as iron sulfate; culture 2, plants grown with 0.01 p.p.m. of iron as chelated iron; culture 3, plants grown with 0.5 p.p.m. of iron as chelated iron.

manganese content of the leaves analyzed was dependent on the concentration of this element in the nutrient solution. Manganese absorption was greatest from the nutrient solution maintained at a pH of 5 than from the one maintained at a pH of 7.

In conclusion, inorganic iron as iron sulfate was ineffective in maintaining soybean plants devoid of chlorosis at a pH of 7. The fact that only chelated iron in adequate amounts was capable of maintaining soybean plants healthy without any evidence of iron-induced chlorosis at a pH of 7 of the nutrient solution suggests the feasibility of using chelated iron in alkaline soils under field conditions to control iron-induced chlorosis due to high pH of the soil.

SUMMARY

Soybean plants, variety Lincoln, were grown in solution cultures at two pH levels, 5 and 7, to determine the effectiveness of iron sequestrene in maintaining iron available to the plants. The results obtained may be summarized as follows:

1. Plants grown in nutrient solution maintained at pH 5 and receiving

the lowest level of chelated iron (0.01 p.p.m. of iron) developed iron chlorosis in the upper leaves while plants grown at pH 5, but receiving inorganic iron as iron sulfate, and chelated iron in amounts of 0.5 p.p.m., developed healthy without any sign of iron-deficiency symptoms.

2. Iron-deficiency symptoms were characterized by a yellowing of the upper leaves followed by crinkling of these leaves and the appearance of small necrotic spots scattered on their surface. In some cases, some reddish pigmentation was noticed.

3. Fresh and dry weights of tops and roots of plants supplied with chelated iron (0.5 p.p.m.) were consistently higher at both pH levels than those of plants supplied with the lowest level of chelated, 0.01 p.p.m., or inorganic iron, 0.5 p.p.m.

4. Upper leaves of plants whether grown at pH 5 or pH 7, but which received 0.01 p.p.m. of chelated iron, had the lowest content of total and soluble iron. These plants were chlorotic.

5. The upper leaves of plants grown at pH 5 and which received chelated or inorganic iron in concentration of 0.5 p.p.m. developed without any sign of iron-deficiency symptoms. However, at pH 7, inorganic iron was ineffective in maintaining healthy plants and iron chlorosis developed. At a pH of 7 chelated iron was as effective as at pH 5.

6. The total- and soluble-manganese contents of the upper leaves of plants grown in nutrient solutions maintained at a pH of 5 or 7, respectively, depended on the manganese concentration of the substrate.

RESUMEN

Se sembraron plantas de habichuela soya, variedad Lincoln, en soluciones nutritivas a dos distintos niveles de pH (pH 5, y 7) para determinar el efecto del quelato de hierro en cuanto a mantener el hierro disponible a las plantas. Los resultados obtenidos de este estudio se resumen a continuación.

1. A las plantas en la solución nutritiva con un pH de 5.0 y que recibieron el nivel más bajo quelato de hierro (0.01 p.p.m. de hierro) se les desarrolló una clorosis en las hojas superiores. Las plantas mantenidas en un pH de 5, pero que recibieron hierro inorgánico en forma de sulfato y de quelato en cantidades de 0.5 p.p.m., se desarrollaron normalmente sin manifestar síntomas algunos de deficiencia de hierro.

2. Los síntomas de deficiencia de hierro se caracterizaron por el amarillamiento y arrugamiento de las hojas superiores de la planta y por el desarrollo de pequeños puntos necróticos esparcidos en la superficie de estas hojas. En algunos casos, se notó también un leve color rojizo en las hojas.

3. El peso verde y seco de las plantas y raíces que recibieron quelato de hierro (0.5 p.p.m. de hierro) fué consistentemente superior en ambos niveles

de pH que aquel de las plantas y raíces que recibieron la cantidad mínima de quelato de hierro (0.01 p.p.m.) o hierro inorgánico en cantidad de 0.5 p.p.m.

4. Las hojas superiores de las plantas que crecieron en un pH de 5 ó 7, y que recibieron 0.01 p.p.m. de hierro como quelato, tuvieron la cantidad más baja de hierro total y soluble. Las plantas se veían cloróticas.

5. Las hojas superiores de las plantas que crecieron en un pH de 5, y que recibieron quelato de hierro o hierro inorgánico en cantidad de 0.5 p.p.m., del elemento no demostraron síntoma alguno que pudiera atribuírse a deficiencia de hierro. Sin embargo, en el pH de 7, el hierro inorgánico no logró efecto alguno en mantener las plantas en desarrollo normal, ya que éstas se pusieron cloróticas. Cuando se usó el quelato de hierro a la misma concentración (0.5 p.p.m.), las plantas se desarrollaron normalmente.

6. El el contenido de manganeso total y manganeso soluble en las hojas de las plantas desarrolladas en soluciones nutritivas con pH de 5 ó 7, estuvo relacionado con la concentración del manganeso del medio nutritivo.

LITERATURE CITED

1. Alexander, C. C., and Walsh, D. J., New chemical agent makes possible complete control of iron chlorosis, *Agr. Chem.* **7** (7) 36–8, 1952.
2. Chapman, H. D., Liebig, G. F., Jr., and Vanselow, A. P., Some nutritional relationships as revealed by a study of mineral deficiency and excess symptoms on citrus, *Proc. Soil Sci. Soc. Amer.* **4** 196–200, 1939.
3. Hopkins, E. F., Pagan, V., and Ramírez-Silva, F. J., Iron and manganese in relation to plant growth, and its importance in Puerto Rico, *J. Agr. Univ. of P. R.* **28** 43–101, 1944.
4. Jacobson, L., Maintenance of iron supply in nutrient solutions by a single addition of ferric potassium ethylenediamine tetraacetate, *Plant Physiol.* **26** 411–3, 1951.
5. Johnson, M. O., The spraying of yellow pineapple plants on manganese soils with iron sulfate solutions, Hawaii Agr. Exp. Sta. Bul. 51, 1916.
6. ——, Manganese chlorosis of pineapples: Its cause and control, Hawaii Agr. Exp. Sta. Bul. 52, 1924.
7. Kelley, W. P., The influence of manganese on the growth of pineapples, Hawaii Agr. Exp. Sta. Bul. 23, 1908.
8. Samuels, G., and Cibes, H. R., Iron chlorosis on *Dracaena sanderiana*, *J. Agr. Univ. P. R.* **37** (4) 265–72, 1953.
9. Stewart, I., and Leonard, C. D., Chelates as sources of iron for plants growing in the field, *Sci.* **116** 564–6, 1952.
10. ——, Iron chlorosis: Its possible causes and control, *Citrus Mag.* **14** (10) 22, 1952.
11. ——, Possible causes and control of iron chlorosis, *Calif. Citrograph* **37** (11) 427, 1952.
12. Toth, S. J., *et al.*, Rapid quantitative determination of eight mineral elements in plant tissue by a systematic procedure involving use of a flame photometer, *Soil Sci.* **66** (6) 459–66, 1948.

RESEARCH NOTE

ON THE PRESENCE OF CROWN GALL IN PUERTO RICO

As far as the writer is aware the only definite reference to the presence of crown gall in Puerto Rico is that presented by Seavers and Chardón[1] in the Scientific Survey of Porto Rico and the Virgin Islands. Under the heading *Pseudomonas tumefaciens* they speak of: ". . . the organism of the crown gall commonly known as 'plant cancers' because of its resemblance to the animal cancer. *The organism is here reported on the strength of the galls found on rose bushes near Arecibo during the recent collecting trip of the senior writer. No attempts were made to isolate the organism.*"

As can readily be seen evidence is still lacking in regard to the etiological agent involved or even the experimental transmission of the tumorous overgrowths resembling crown gall occasionally found on plants in the Island.

During May of this year rose plants collected at O. L. Pikes' nursery in Arecibo and exhibiting clear-cut root galls were brought to the laboratory by C. D. Paris of the Station staff. Bits of tissue from these galls were inserted in longitudinal slits about ½ in. long made on the stems of *Lycopersicum esculentum* L. var. Marglobe and *Ricinus communis* L. plants. The grafts were covered with sterilastic and the plants placed in a humid atmosphere for a week.

About a month later all the grafted plants began to develop typical tumorous overgrowths. Attempts are being made to isolate the causal agent of the galls from the tumors developed on the grafted plants.

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[1] Seavers, F. J., and Chardón, C. E., Scientific Survey of Porto Rico and the Virgin Islands, 8, Part 1, p. 10, 1926.

(Continued from inside front cover)

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[2] Leave to pursue studies.